



PCIe® Error Detection and Recovery Mechanisms

Gord Caruk
Fellow Design Engineer
Advanced Micro Devices

Disclaimer



Presentation Disclaimer: All opinions, judgments, recommendations, etc. that are presented herein are the opinions of the presenter of the material and do not necessarily reflect the opinions of the PCI-SIG®.

Reliable Information Exchange



- **PCI Express[®] protocol guarantees reliable information exchange between Tx and Rx**
- **Any single bit error is detectable and recoverable, many in multiple ways**
- **Every bit in a data stream will be exhaustively analyzed for the mechanism that detects that error and what mechanism recovers from it**
- **Other presentations discuss the mechanisms**
- **This presentation attempts to prove that every single-bit-error and many multi-bit-errors are recovered from**

Error Modes



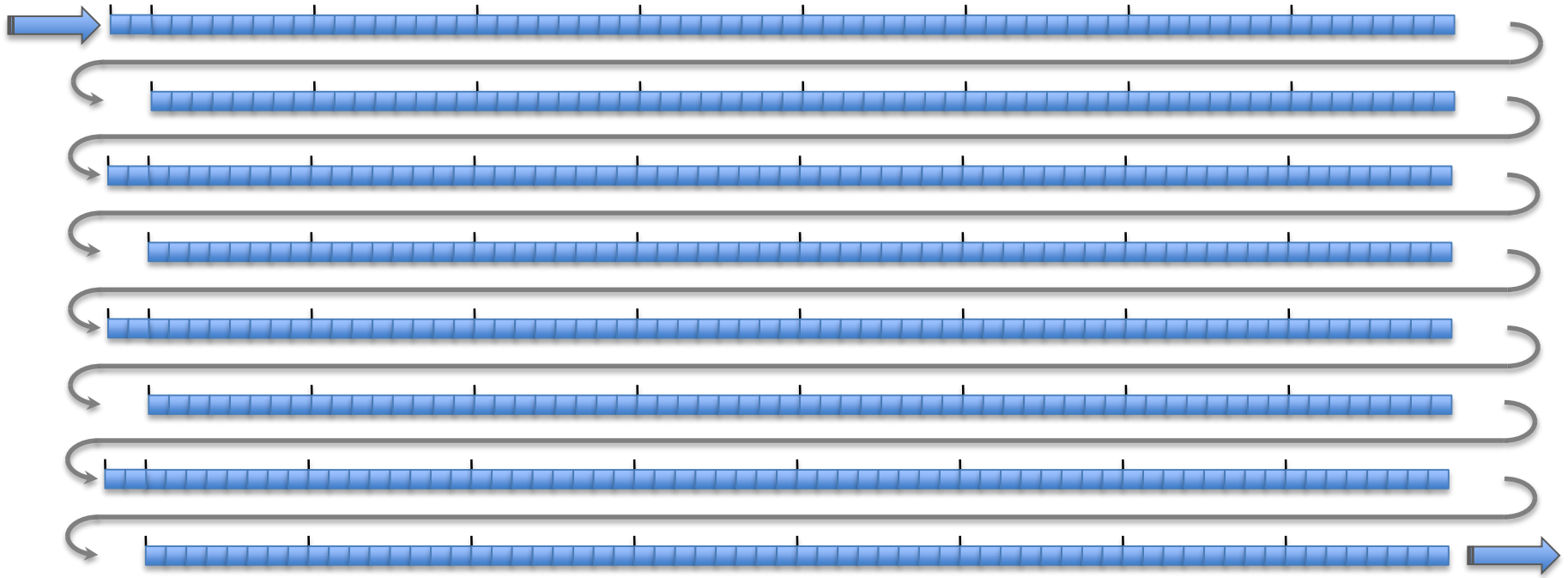
- **Single Bit Error**
- **Slip a bit (pick or drop) – many bits in error**
- **CDR loses lock completely – many bits in error**

CRC Coverage



- **TLP LCRC – 3 bit flips**
- **Framing Token CRC – 3 bit flips**
- **DLLP CRC – 4 bit flips**
- **See the Phy Logical presentation**

Serial Bitstream



Packet Stream Example



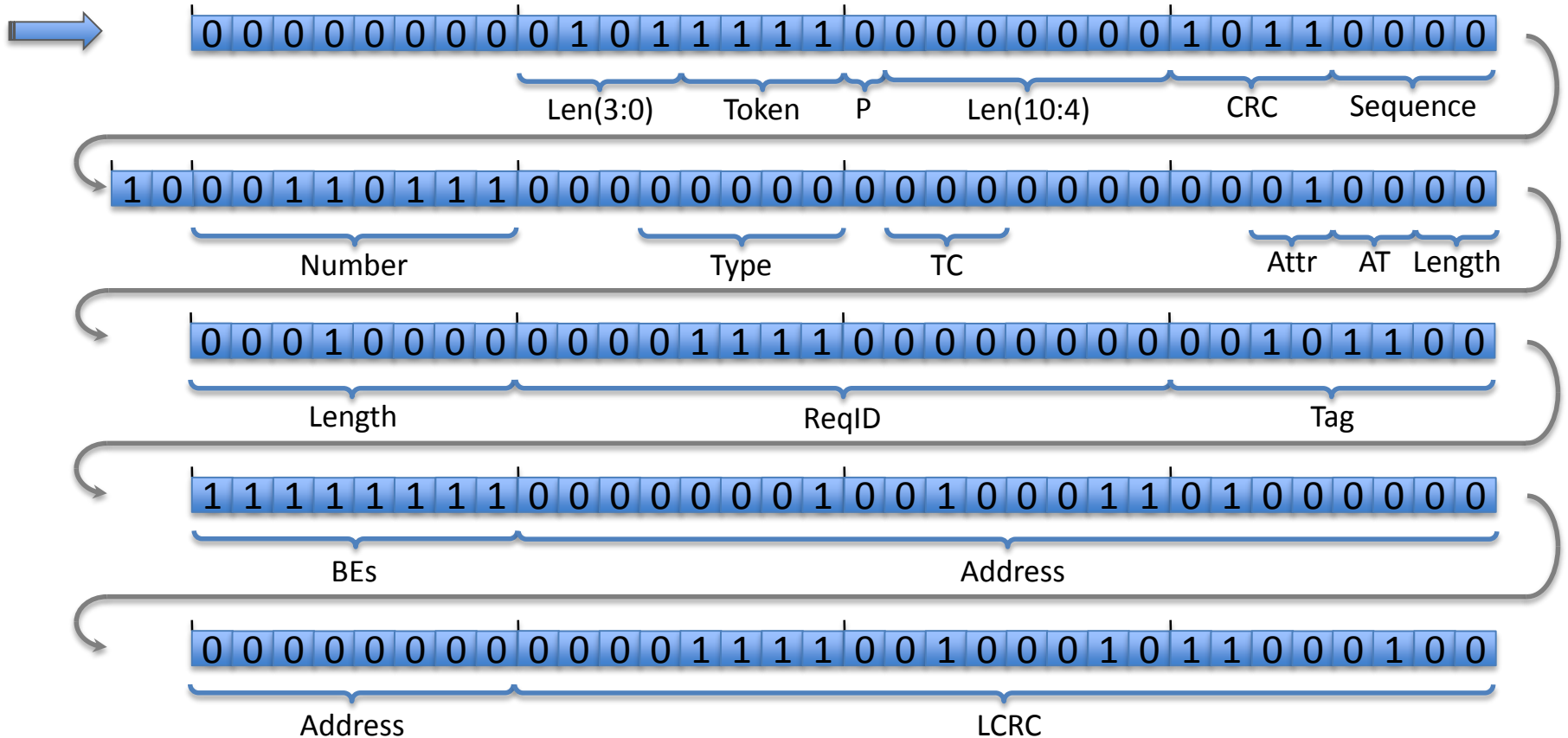
- **Memory write:**
 - address 1234000h
 - data abcdef
- **Memory Read**
 - address 1234000h
- **FCCU DLLP**
- **TS1 Ordered Set**

Memory Read TLP Fields

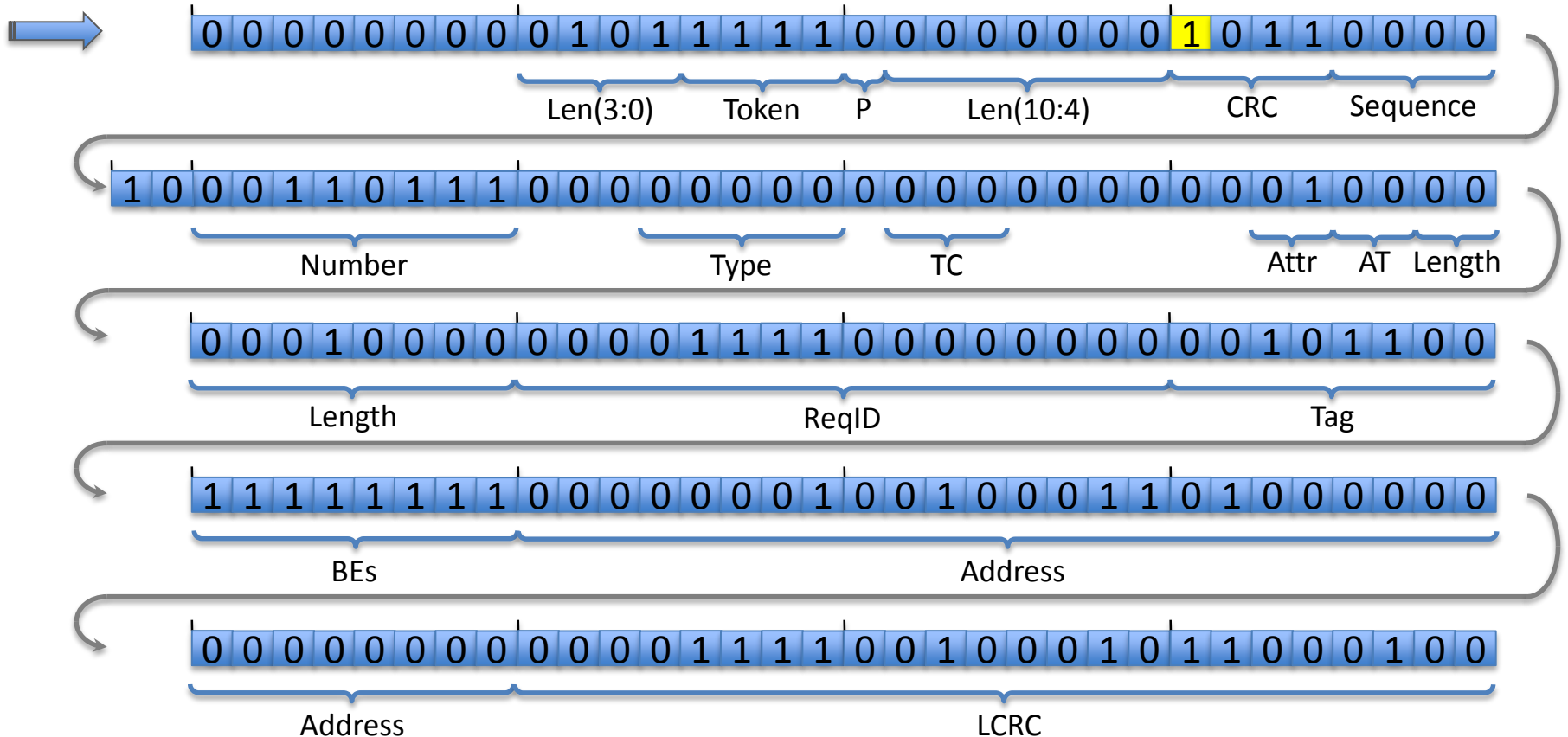


- **Sync header = 10**
- **Framing token type = F**
- **TLP length = 5**
- **Sequence number = 37**
- **Format = 0 (3DW no payload)**
- **Type = 0 (memory read)**
- **Traffic Class = 0**
- **Attributes = 1 (relaxed ordering)**
- **Length = 16 (64B)**
- **Requester ID = 0F00 (B=F, D=0, F=0)**
- **Tag = 2C**
- **FBE = F, LBE = F**
- **Address = 01234000**

Serial Bitstream

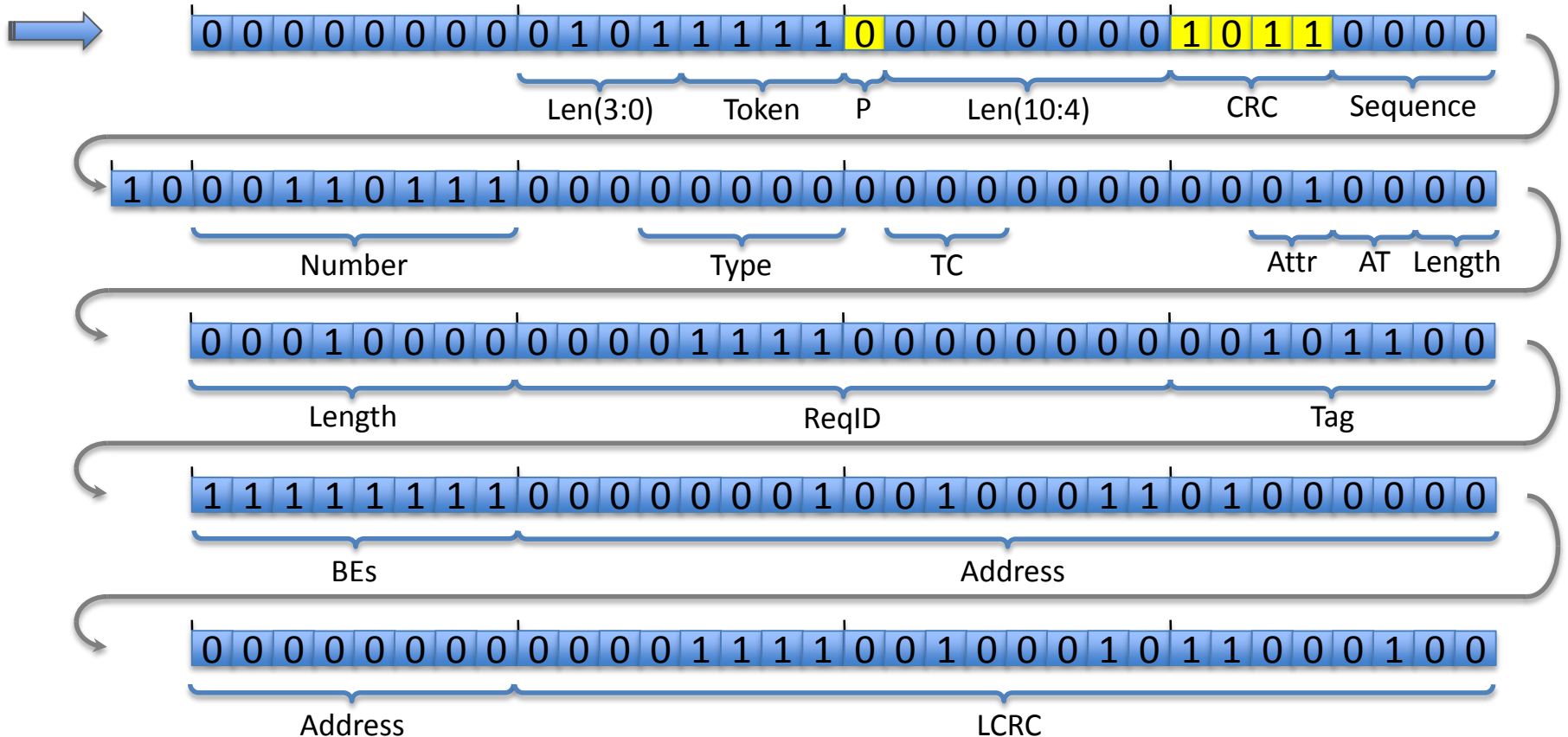


Serial Bitstream



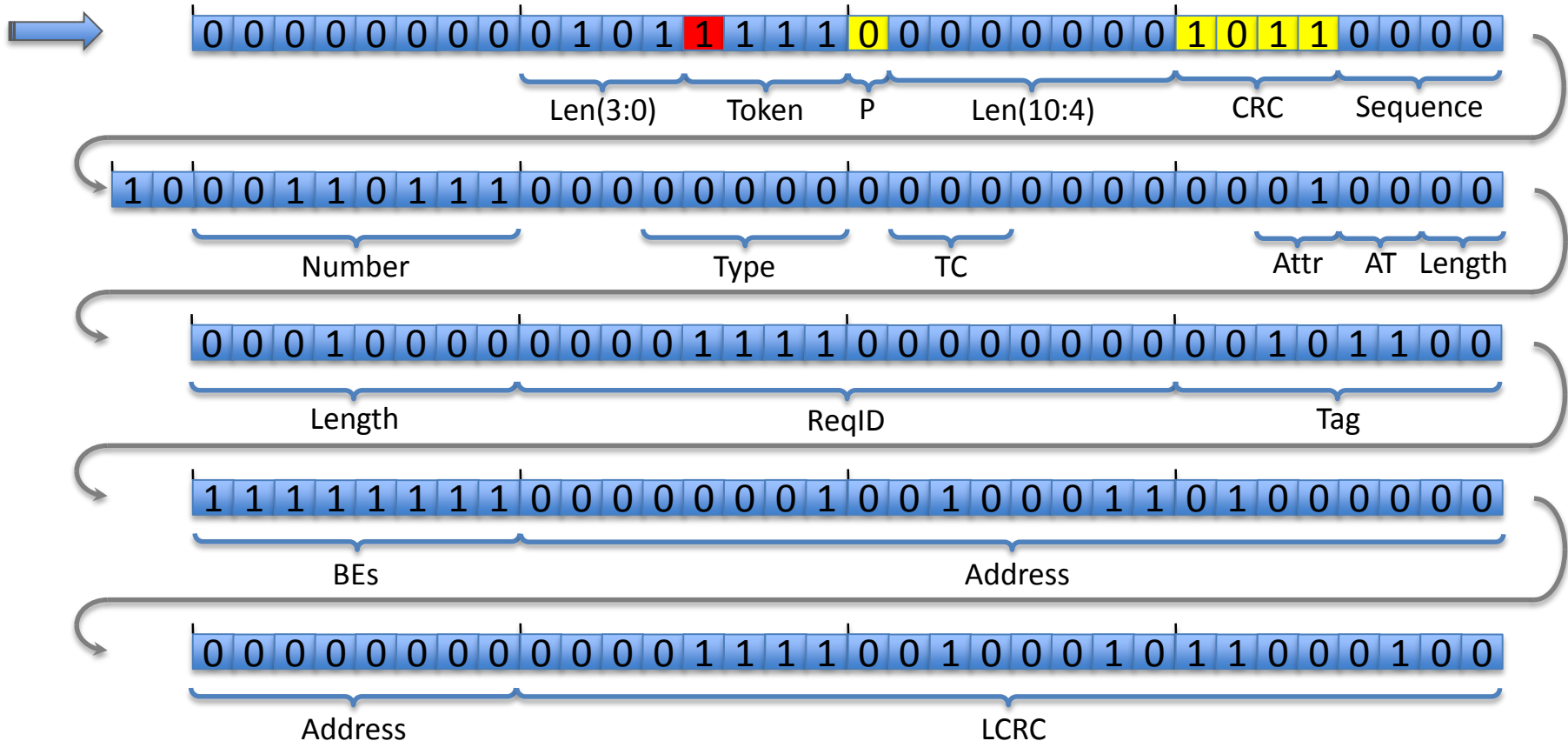
0 CRC Error – Framing Error – Recovery - Replay

Serial Bitstream



0 CRC Error – Framing Error – Recovery - Replay

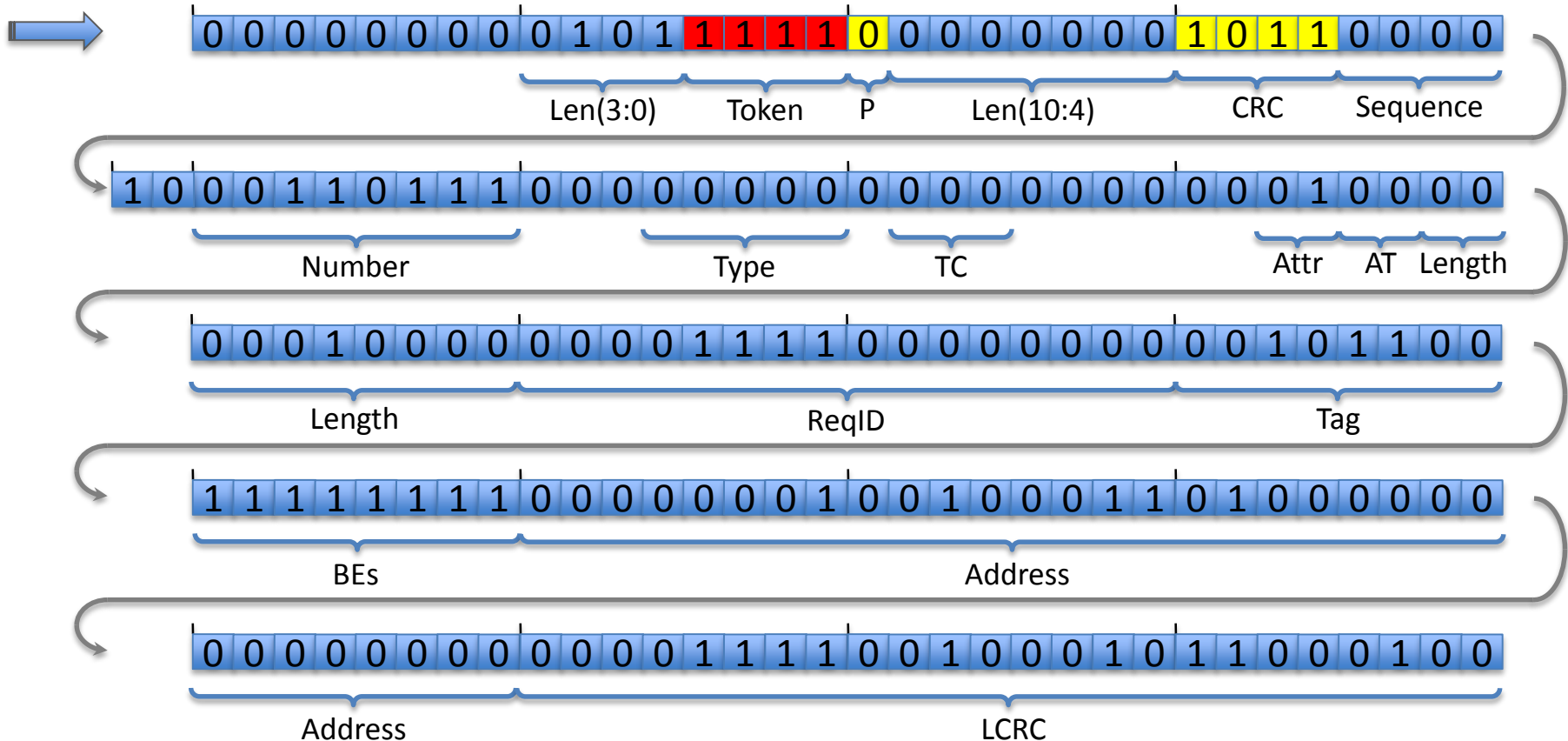
Serial Bitstream



0 Framing Error – Recovery - Replay

0 CRC Error – Framing Error – Recovery - Replay

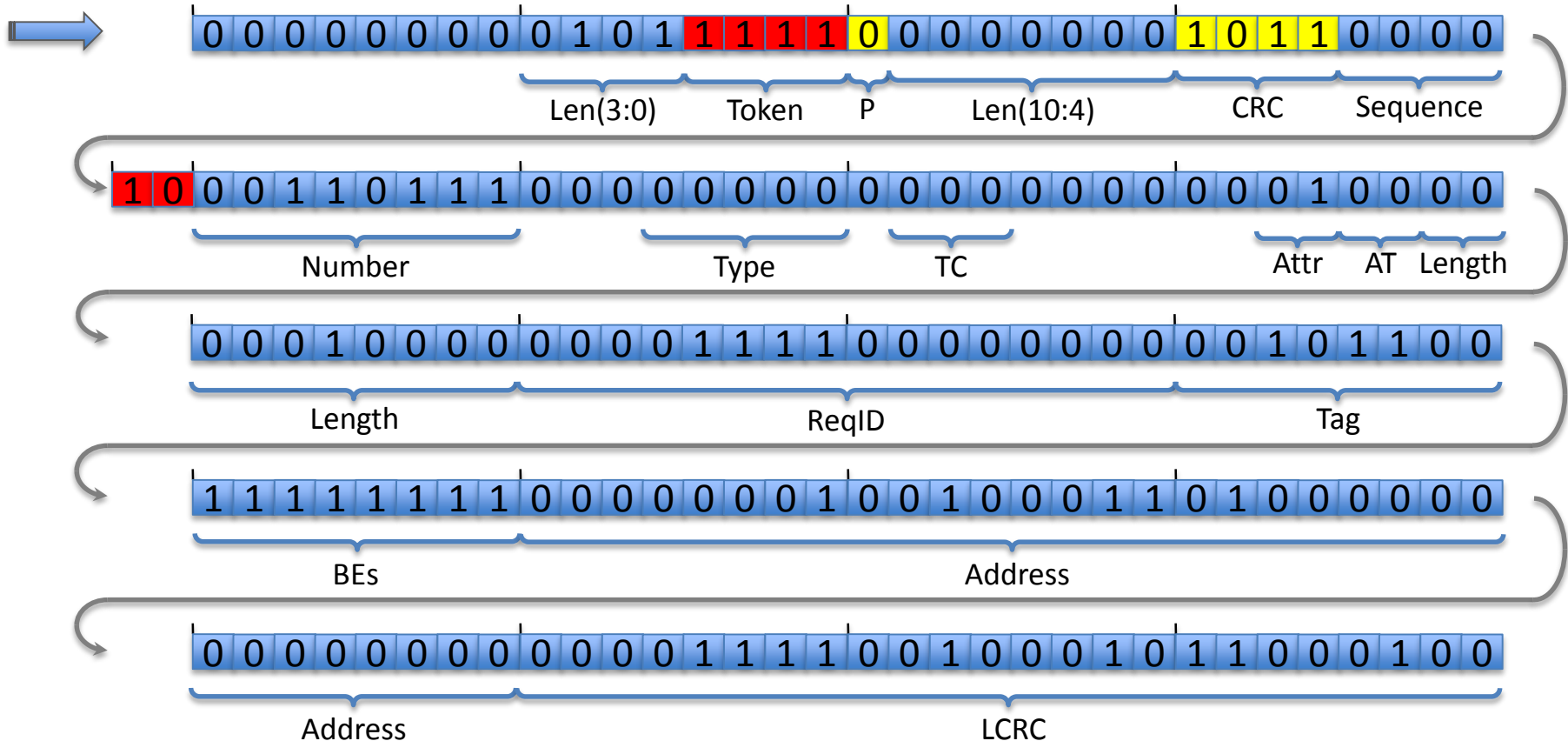
Serial Bitstream



0 Framing Error – Recovery - Replay

0 CRC Error – Framing Error – Recovery - Replay

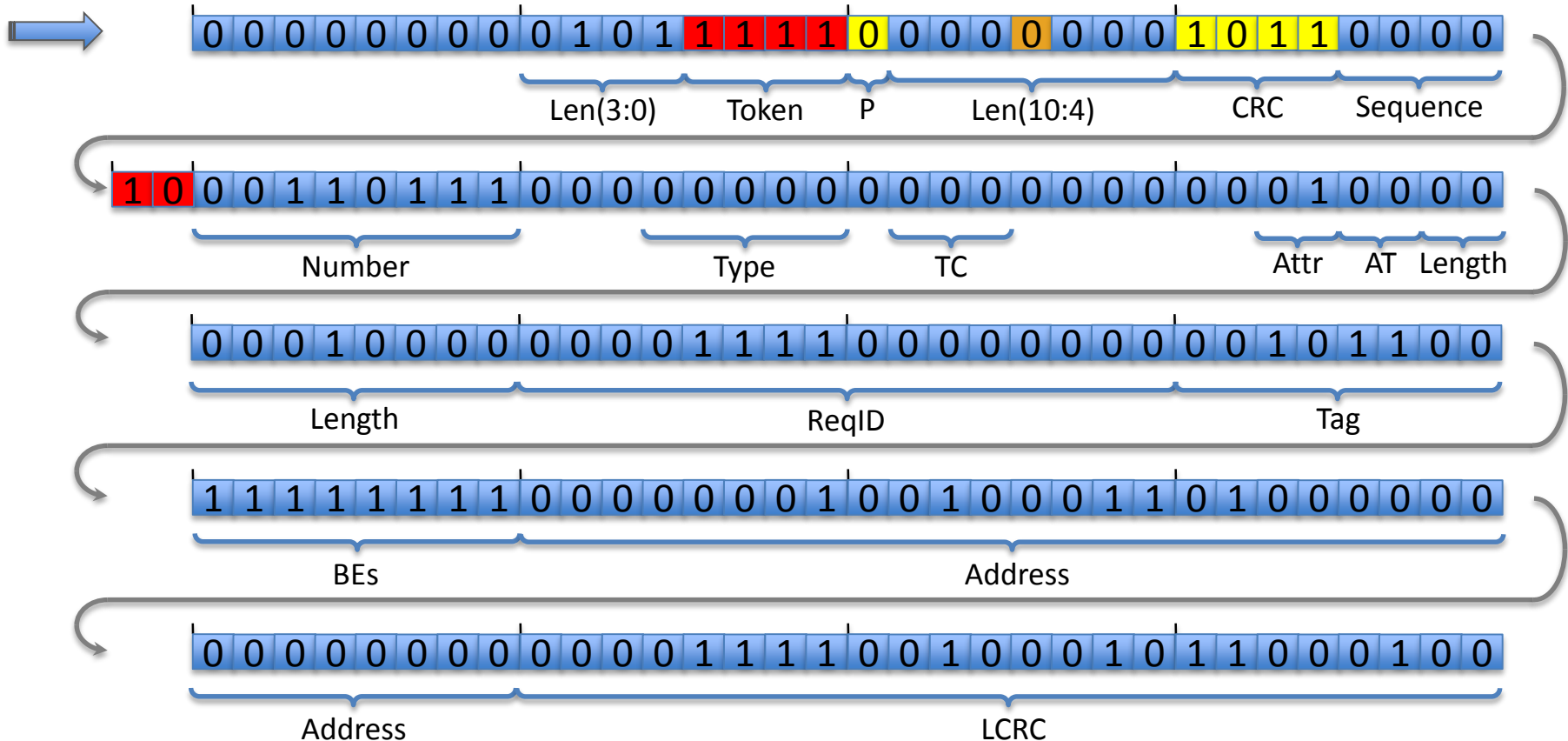
Serial Bitstream



0 Framing Error – Recovery - Replay

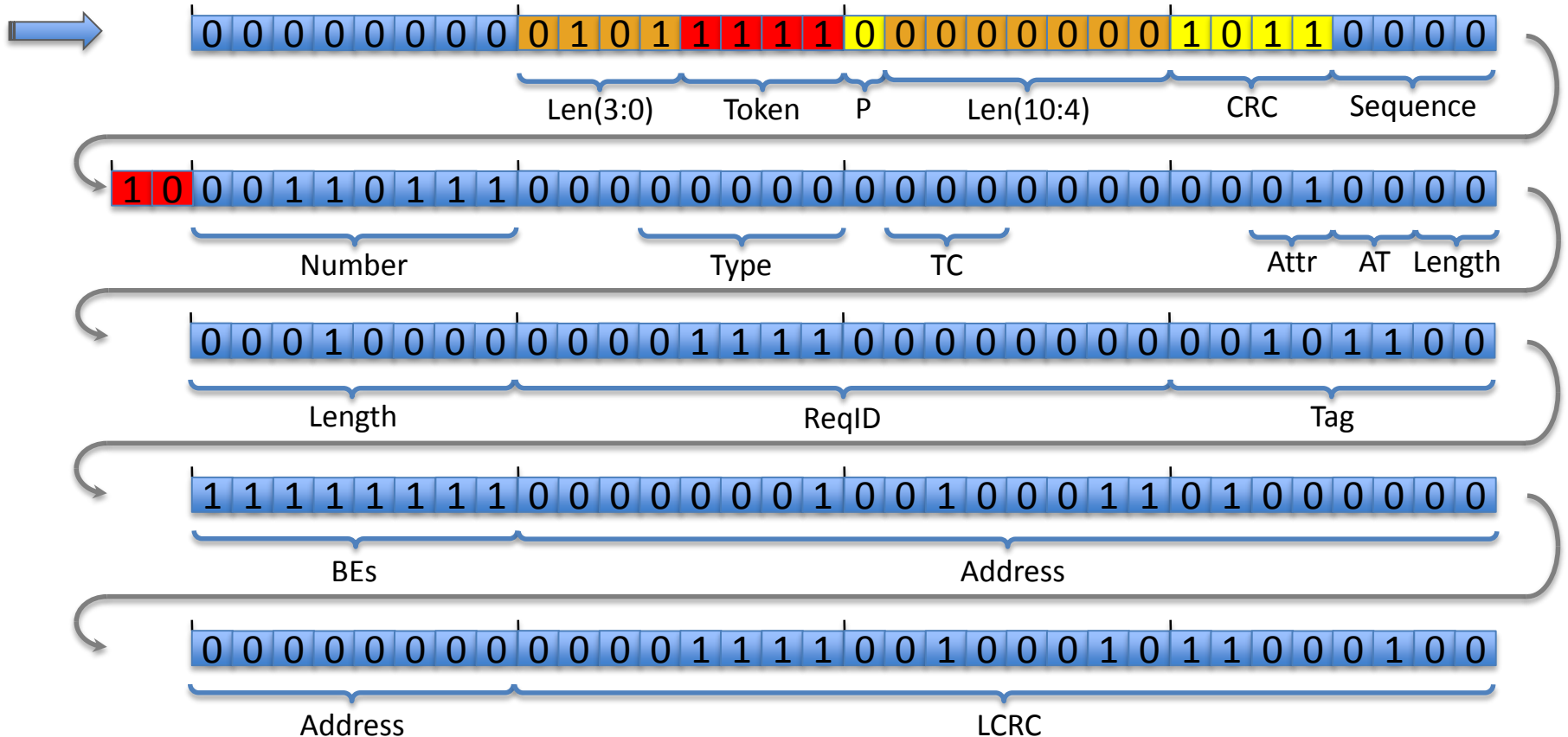
0 CRC Error – Framing Error – Recovery - Replay

Serial Bitstream



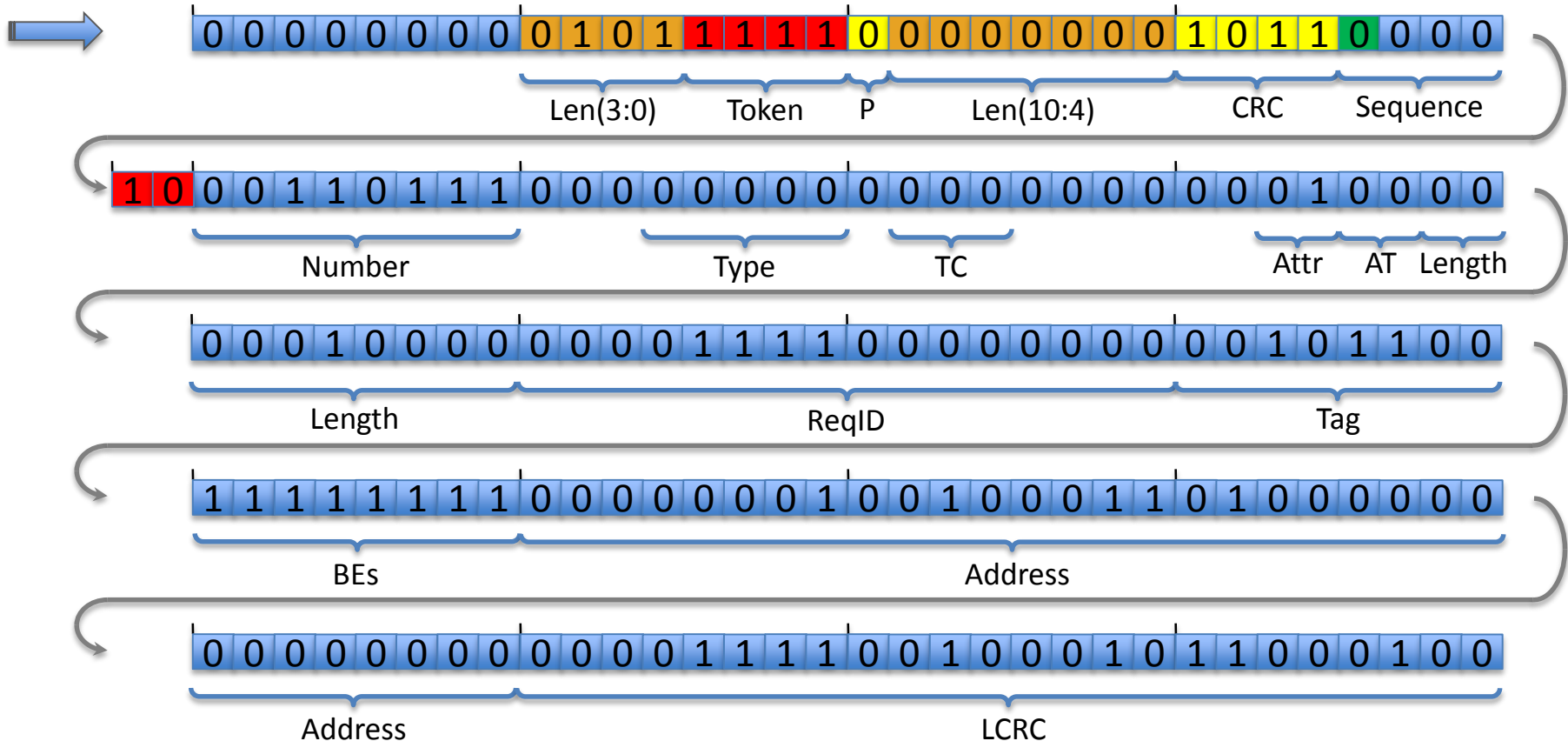
- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay
- 0 CRC Error – Framing Error – Recovery - Replay

Serial Bitstream



- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay
- 0 CRC Error – Framing Error – Recovery - Replay

Serial Bitstream

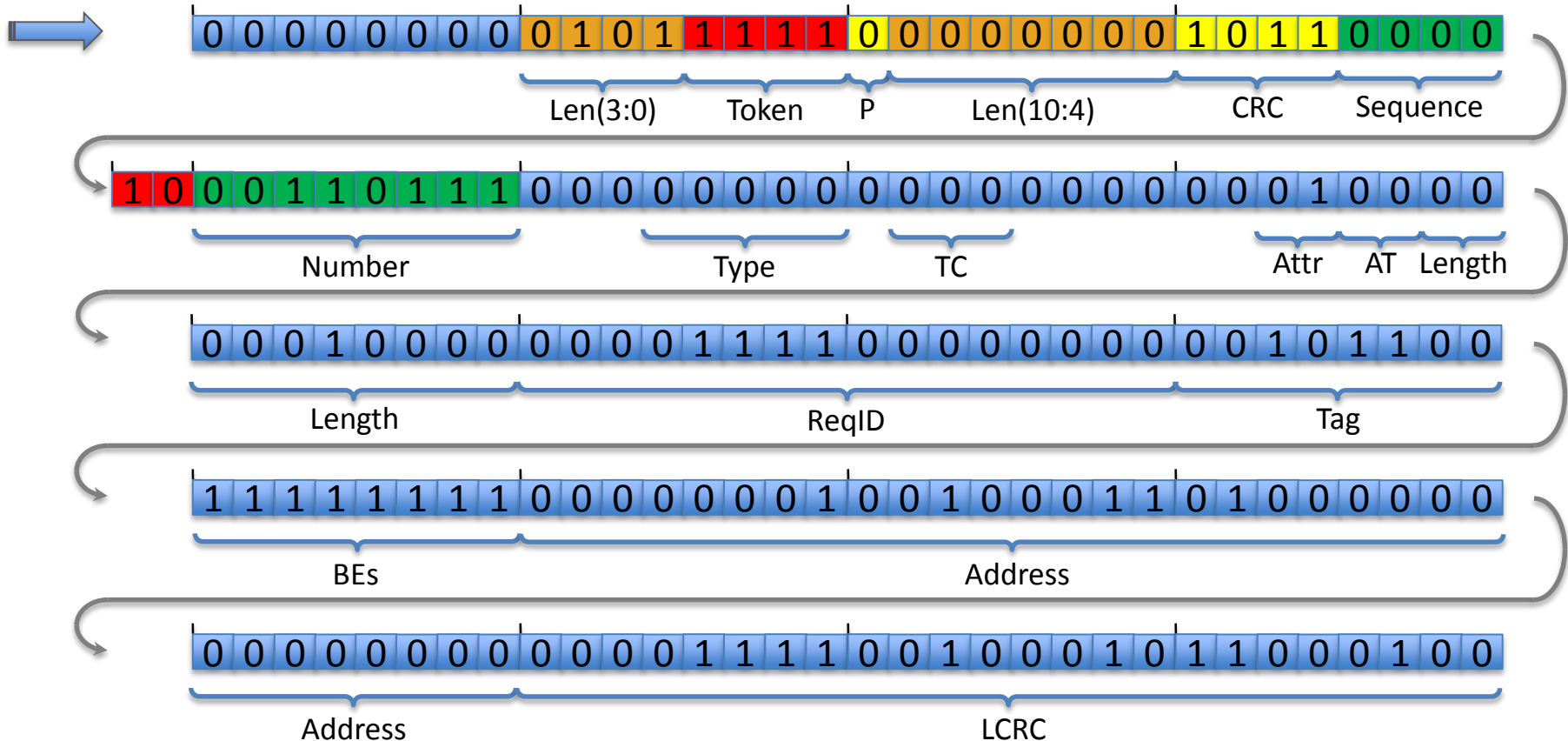


0 LCRC Error – Nak - Replay
0 Framing Error – Recovery - Replay

0 CRC Error – Framing Error – Recovery - Replay

0 Sequence Error – Nak – Replay

Serial Bitstream



LCRC Error – Nak - Replay



Framing Error – Recovery - Replay

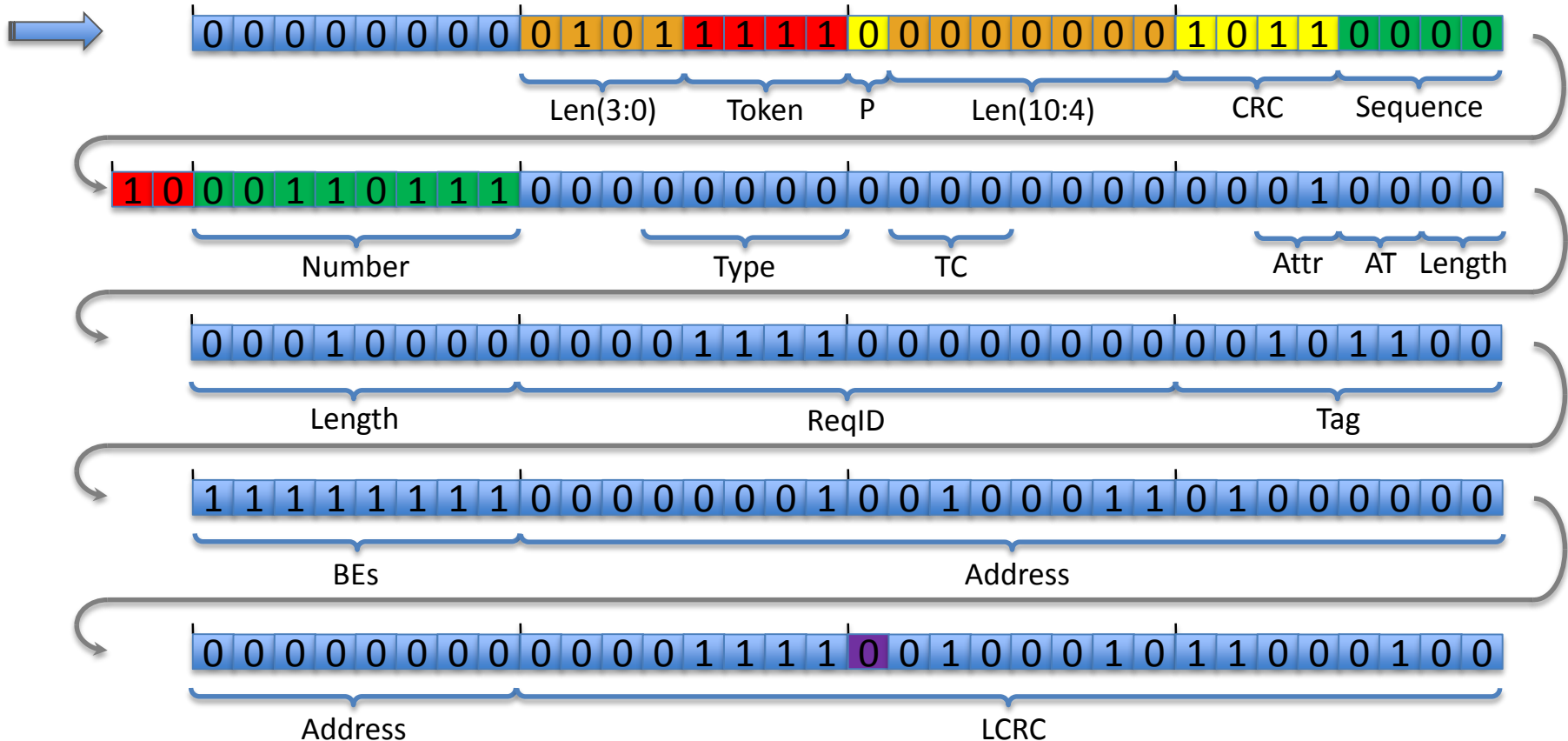


CRC Error – Framing Error – Recovery - Replay



Sequence Error – Nak – Replay

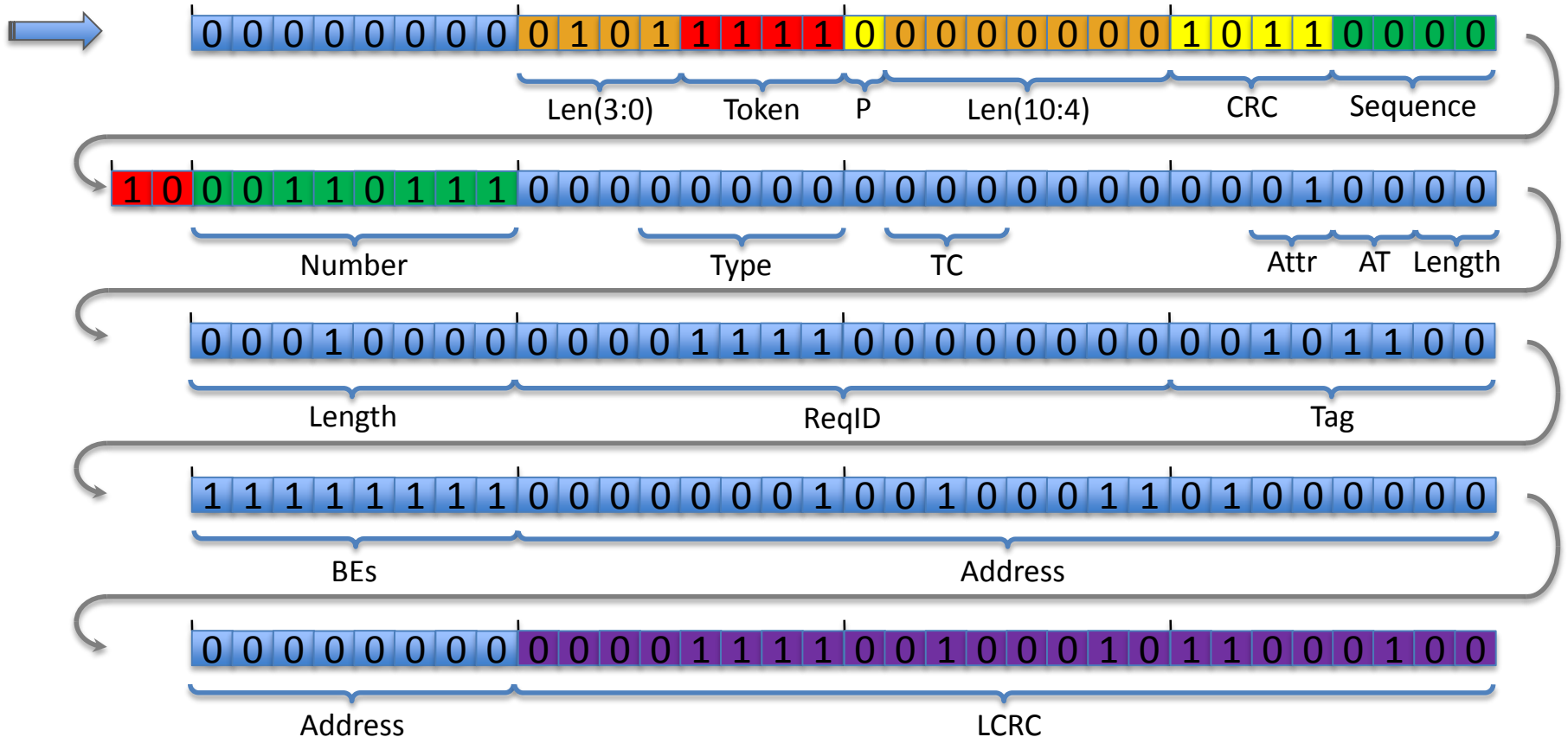
Serial Bitstream



- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay
- 0 CRC Error – Framing Error – Recovery - Replay

- 0 LCRC Error – Nak - Replay
- 0 Sequence Error – Nak – Replay

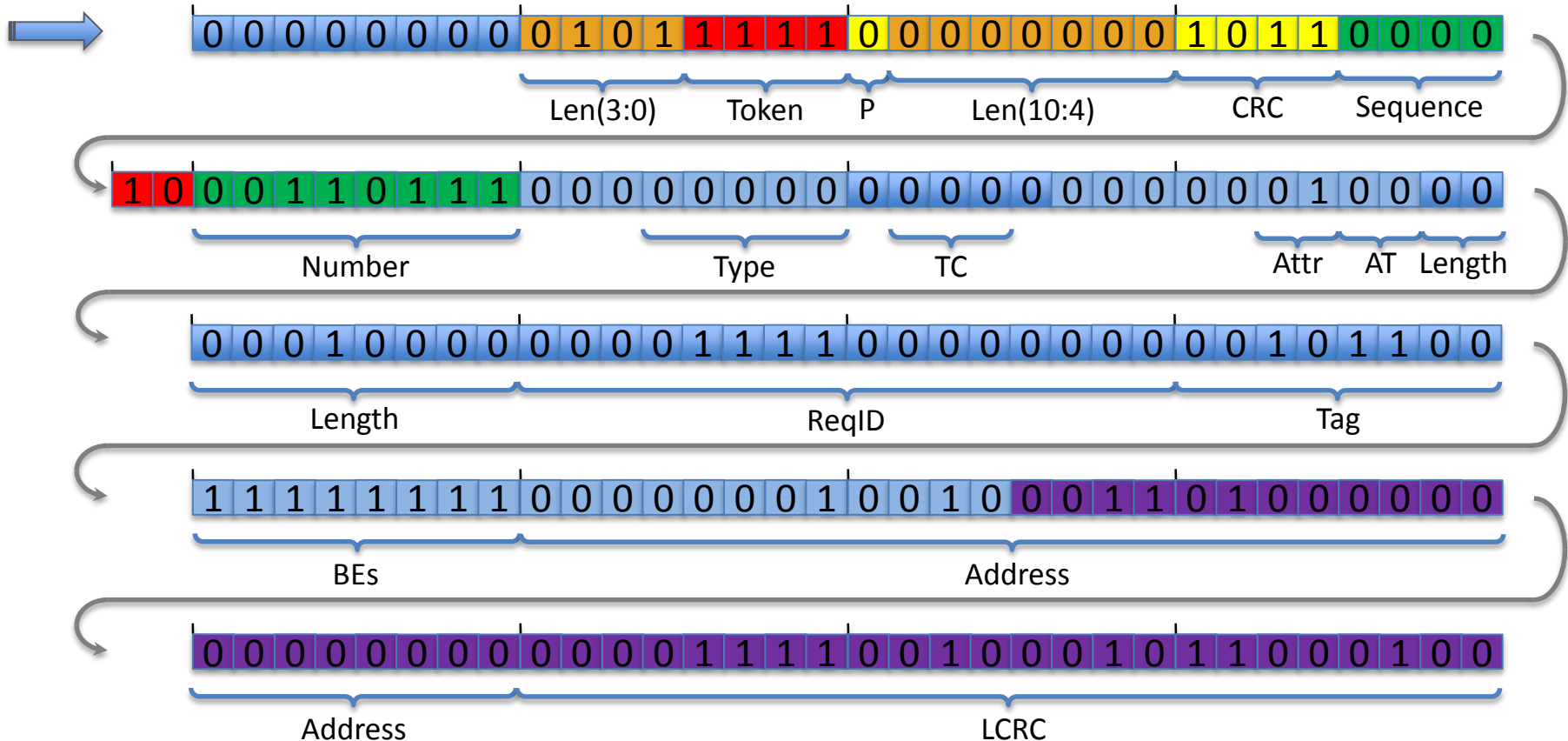
Serial Bitstream



- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay
- 0 CRC Error – Framing Error – Recovery - Replay

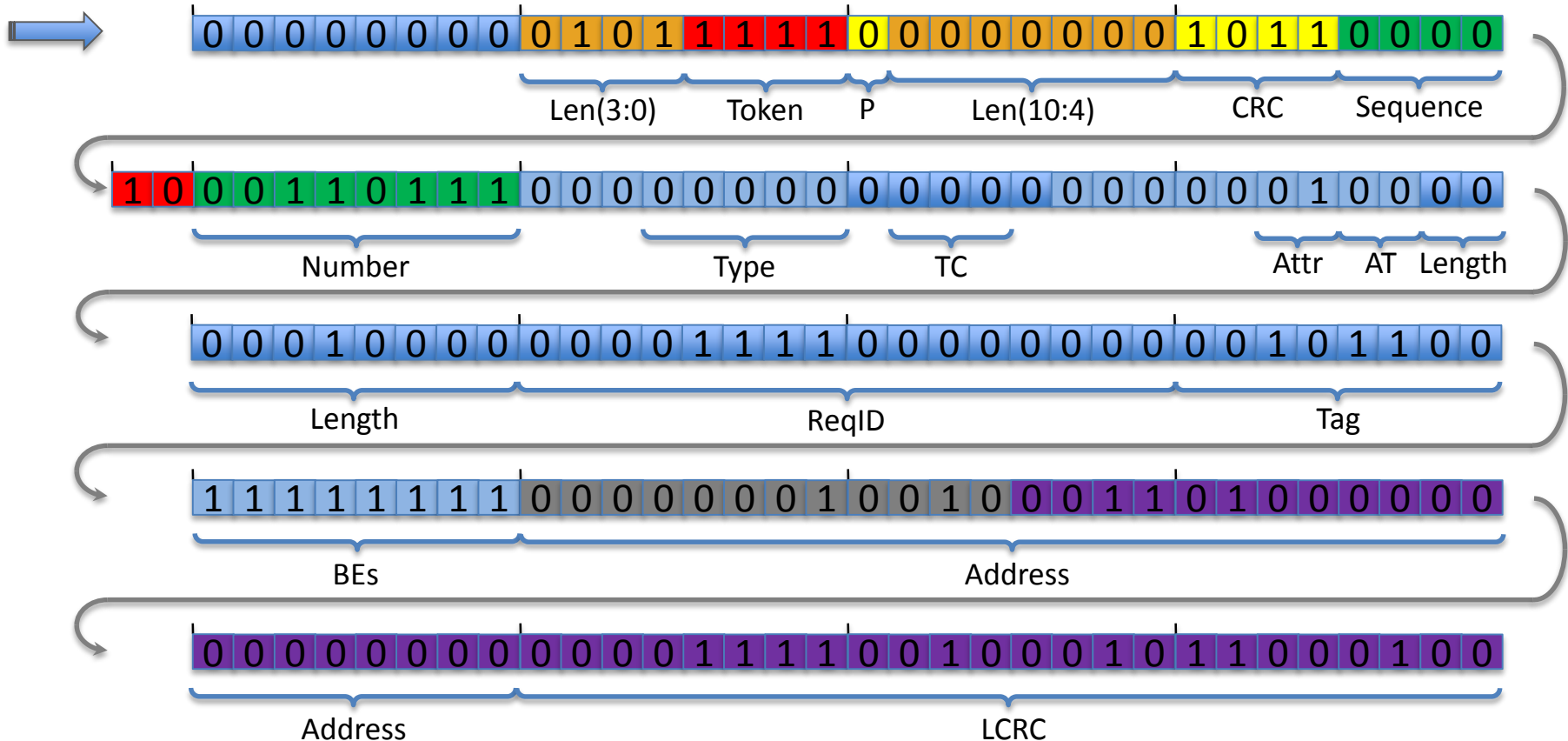
- 0 LCRC Error – Nak - Replay
- 0 Sequence Error – Nak – Replay

Serial Bitstream



- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay
- 0 LCRC Error – Nak - Replay
- 0 Sequence Error – Nak – Replay
- 0 CRC Error – Framing Error – Recovery - Replay

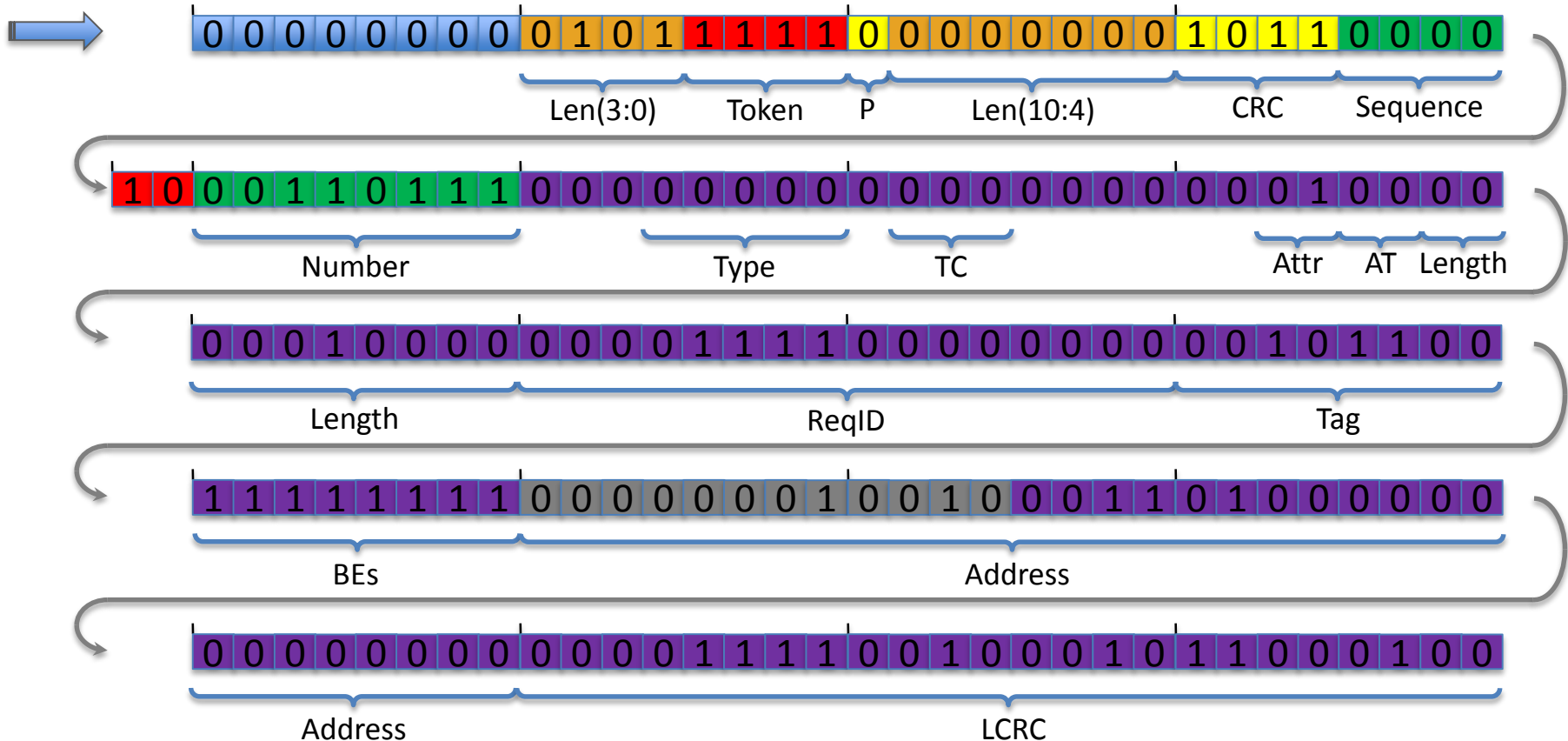
Serial Bitstream



- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay
- 0 CRC Error – Framing Error – Recovery - Replay

- 0 Address Decode Error - UR
- 0 LCRC Error – Nak - Replay
- 0 Sequence Error – Nak – Replay

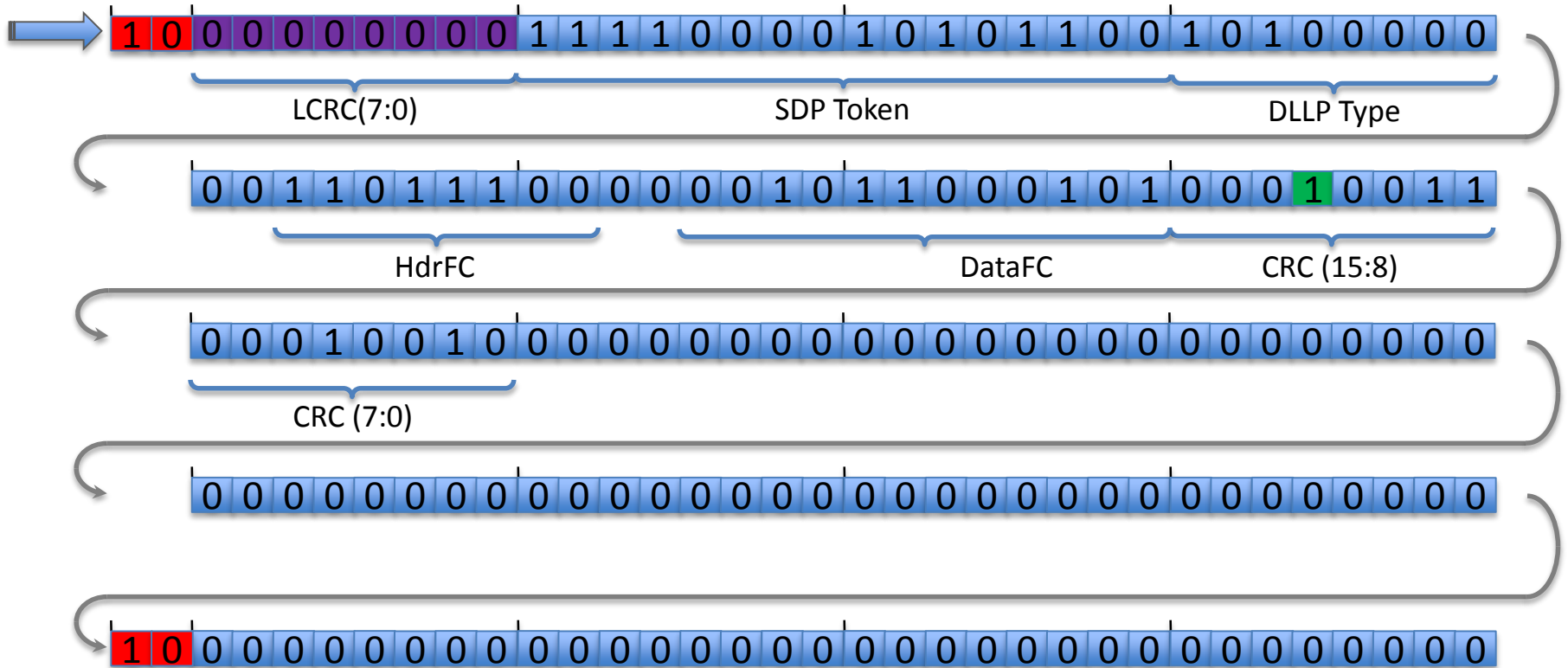
Serial Bitstream



- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay
- 0 CRC Error – Framing Error – Recovery - Replay

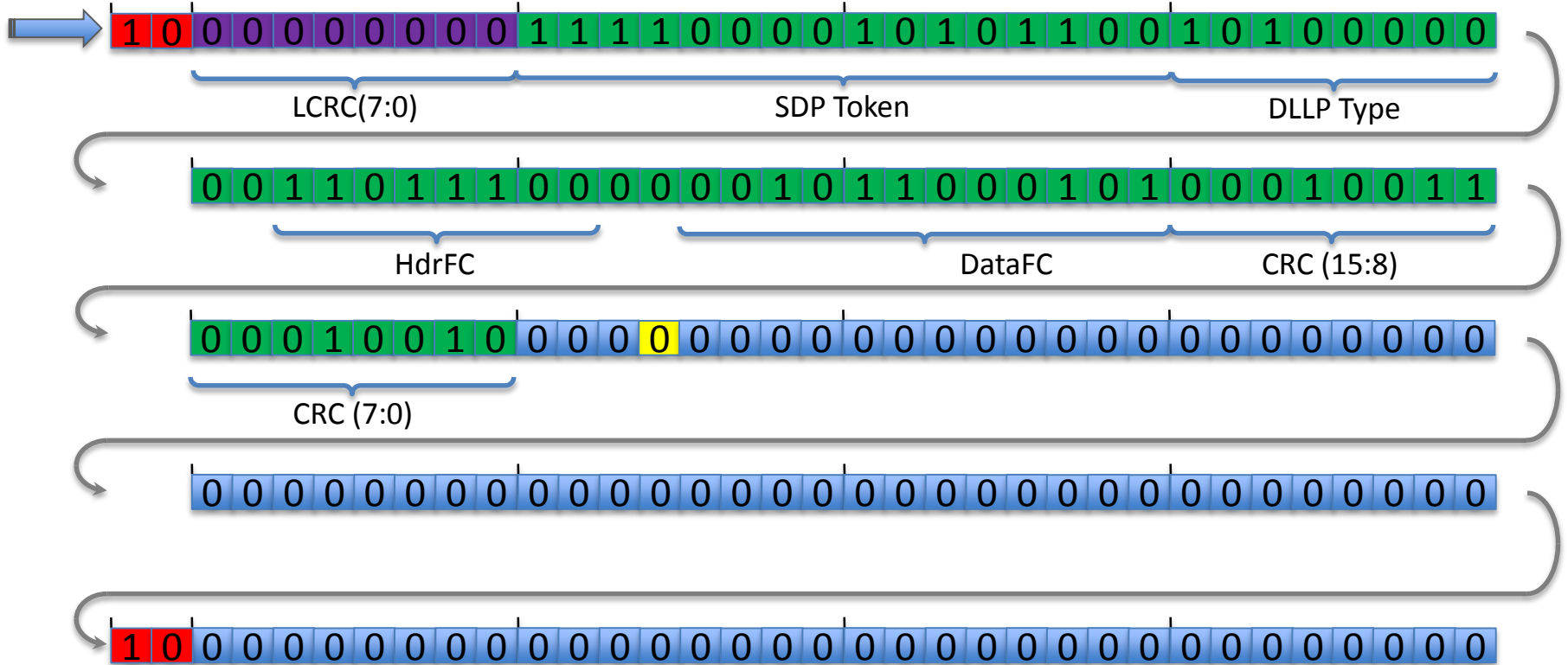
- 0 Address Decode Error - UR
- 0 LCRC Error – Nak - Replay
- 0 Sequence Error – Nak – Replay

Serial Bitstream



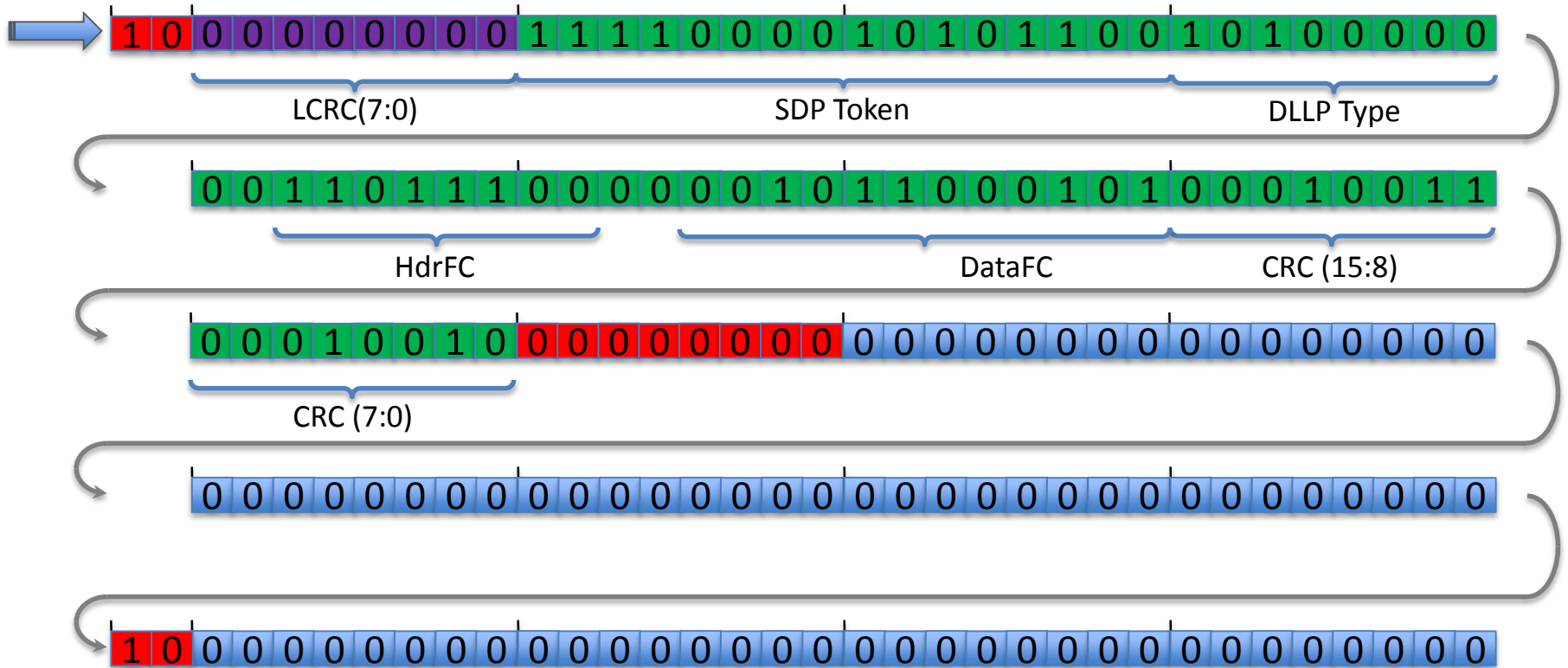
- 0 DLLP CRC Error – Throw Away – Next DLLP
- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay

Serial Bitstream



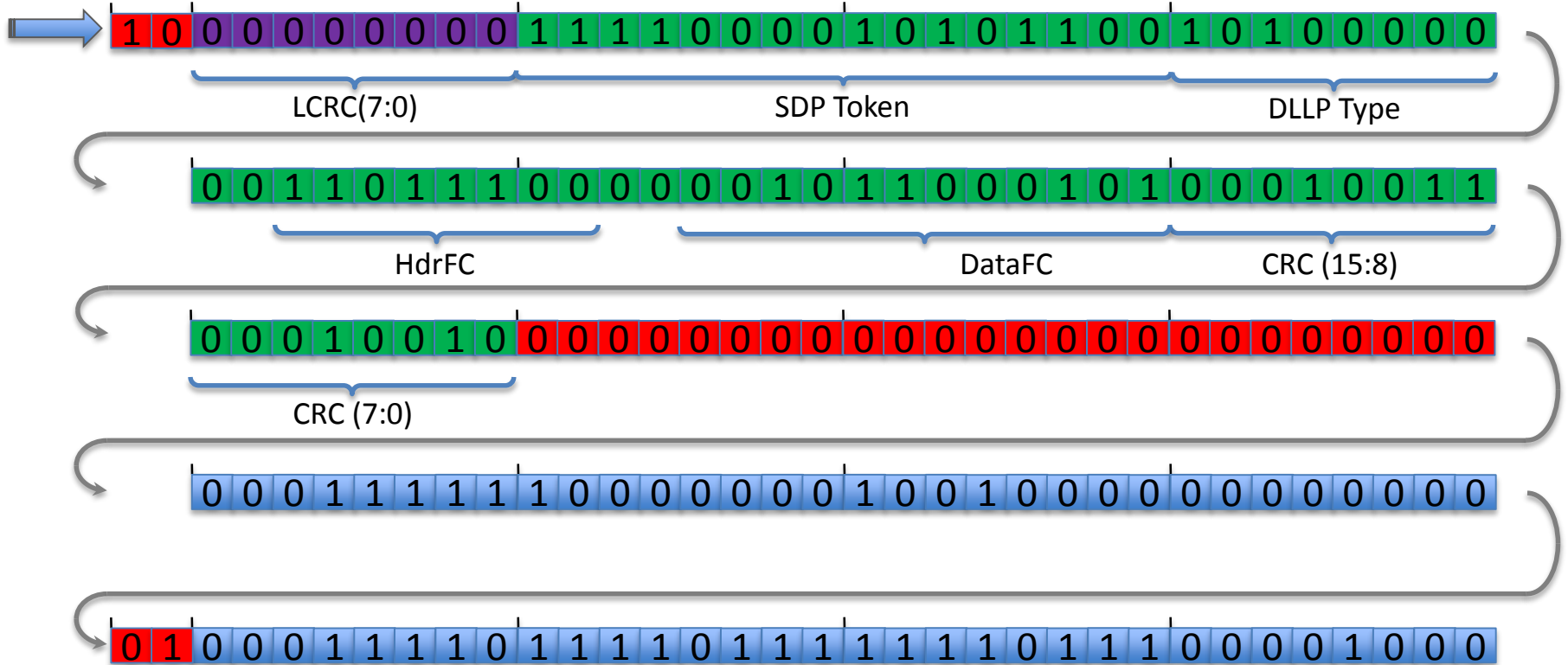
- 0 DLLP CRC Error – Throw Away – Next DLLP
- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay

Serial Bitstream



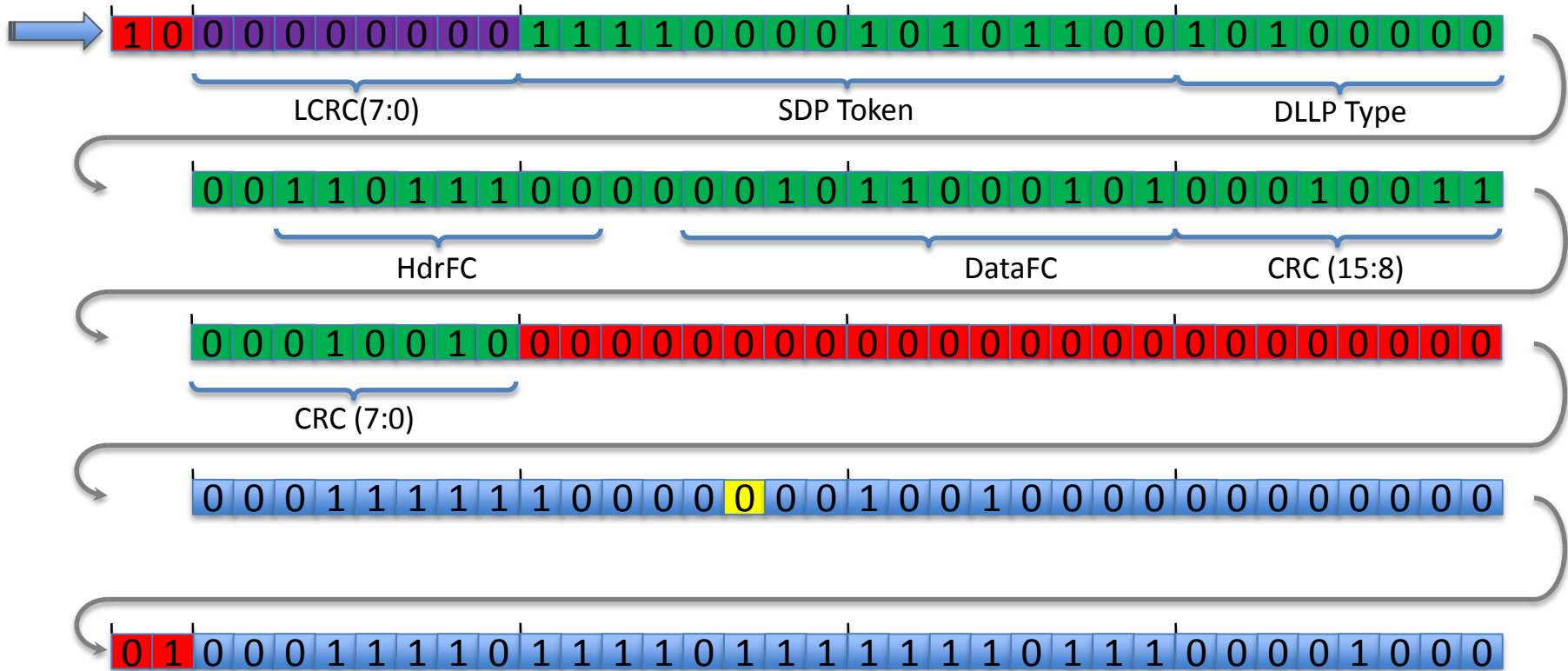
- 0 DLLP CRC Error – Throw Away – Next DLLP
- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay

Serial Bitstream



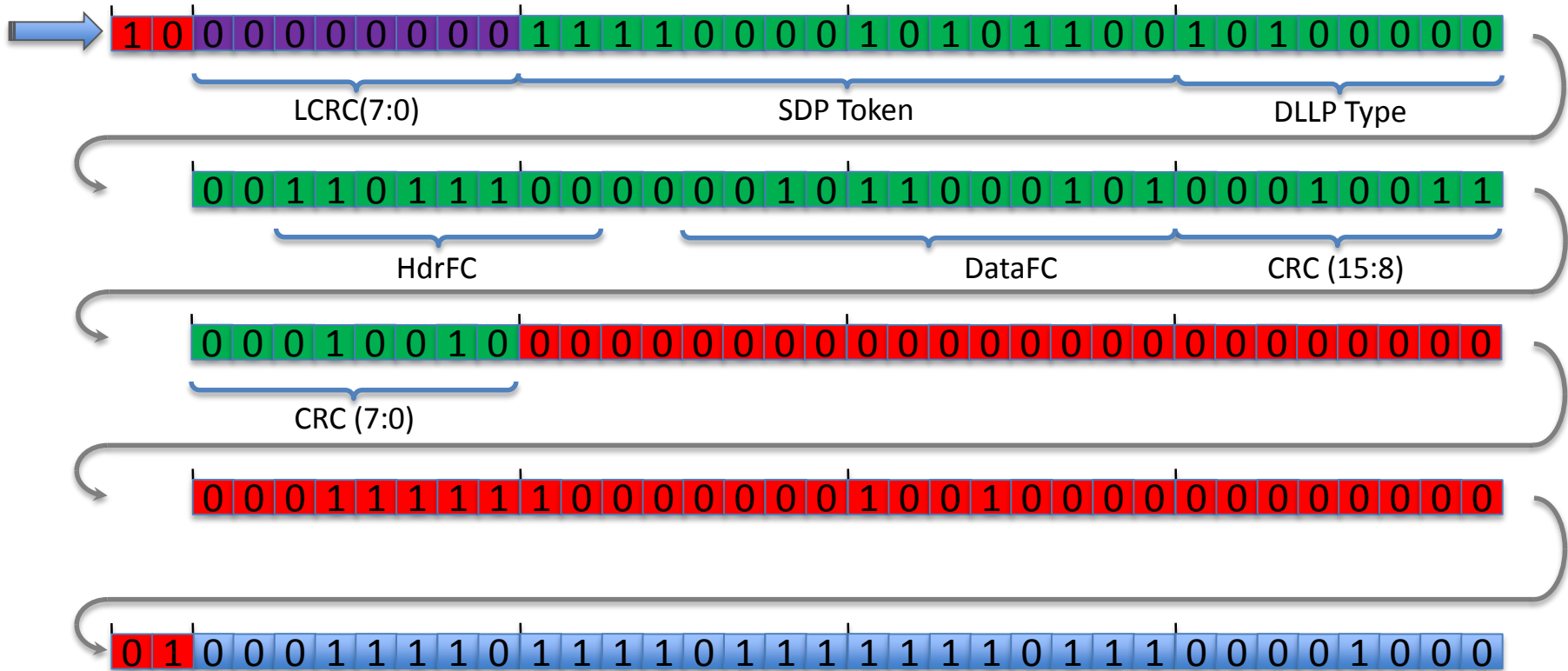
- 0 DLLP CRC Error – Throw Away – Next DLLP
- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay

Serial Bitstream



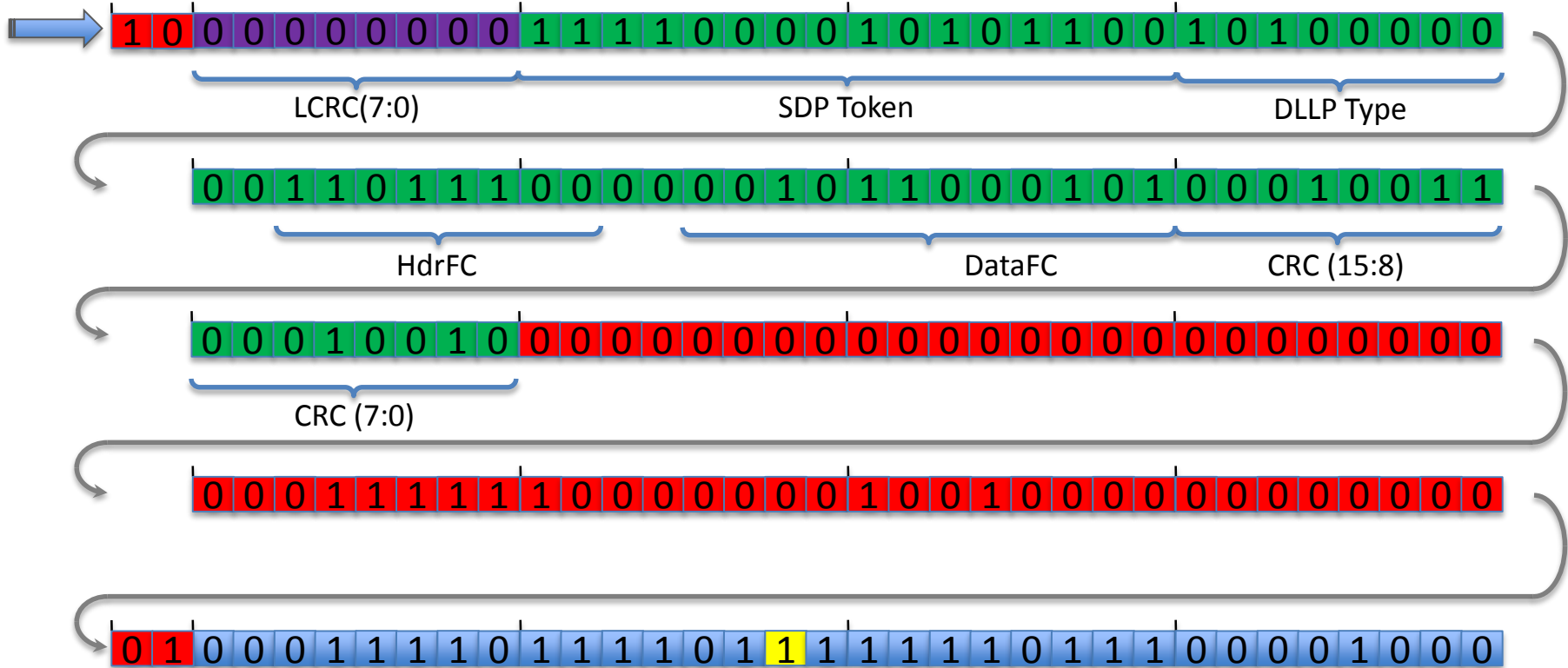
- 0 DLLP CRC Error – Throw Away – Next DLLP
- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay

Serial Bitstream



- 0 DLLP CRC Error – Throw Away – Next DLLP
- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay

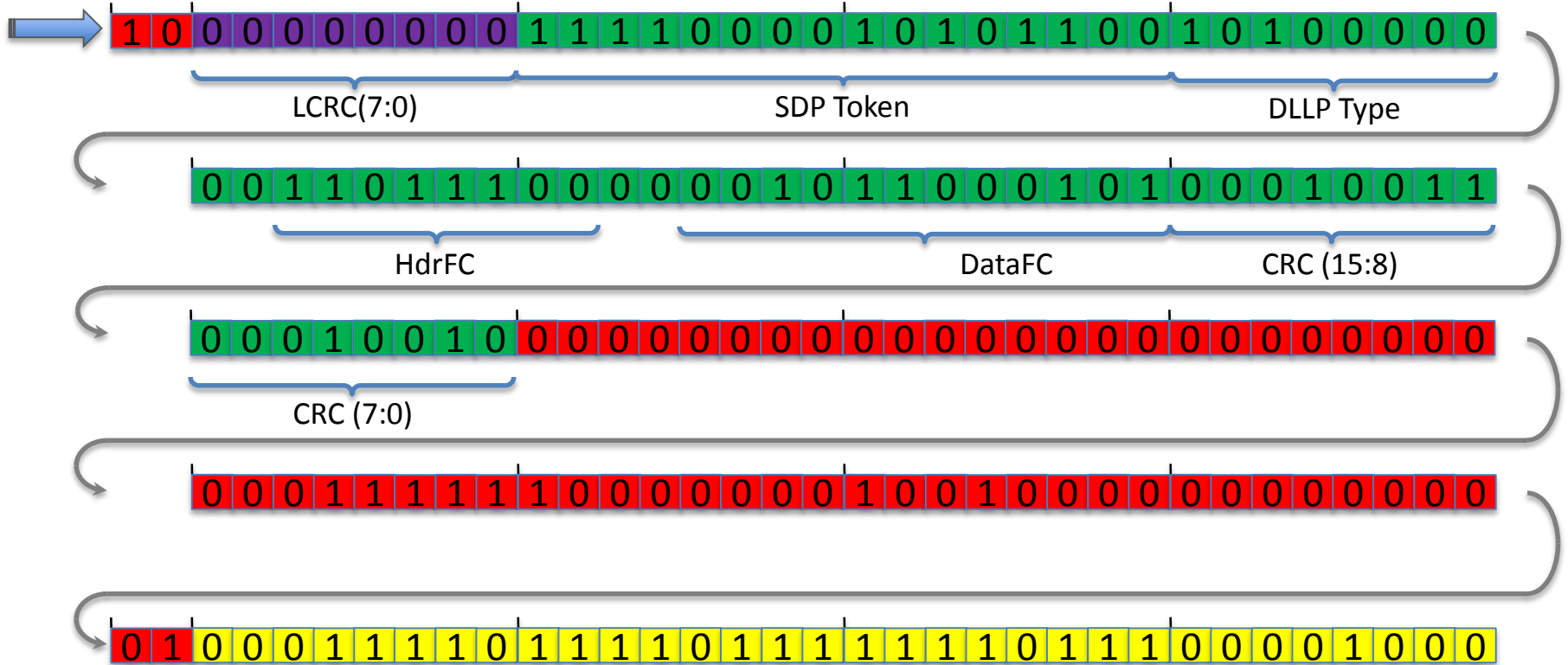
Serial Bitstream



- 0 DLLP CRC Error – Throw Away – Next DLLP
- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay

0 Consecutive OS – Reset Count

Serial Bitstream



- 0 DLLP CRC Error – Throw Away – Next DLLP
- 0 LCRC Error – Nak - Replay
- 0 Framing Error – Recovery - Replay

0 Consecutive OS – Reset Count

Features That Recover



- **Framing Error → Recovery → Replay**
 - 2 us latency
- **LCRC, Sequence Number Error → Nak → Replay**
- **Ack Timeout → Replay**
 - < 100 ns latency
- **Re-send (DLLPs, OSs)**
- **8b/10b Decode Error**
- **Multi-lane Link**

Features That Don't Recover



- **Parity sanity check**
- **Malformed**
- **UR**
- **Many other checks that detect but don't recover**

Conclusion



- **PCI Express protocol guarantees reliable information exchange between Tx and Rx**
- **This presentation has demonstrated that any single bit in error is recovered from, many in multiple ways**
- **Carries forward to more errors, since the CRCs cover 1,2,3 bit errors**

**Thank you for attending the
PCI-SIG Developers Conference 2017.**

**For more information please go to
www.pcisig.com**

